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THE LAG IN RESEARCH
AND EXTENSION
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RESEARCH
AND EXTENSION PROGRAM

FROM

THE WESTERN RANGE—A GREAT
BUT NEGLECTED NATURAL RESOURCE

FOREST SERVICE

U. S. DEPARTMENT OF AGRICULTURE



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THE LAG IN RESEARCH AND EXTENSION

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Management of western ranges with their intricate and variable pattern of conditions and their interlocking private and public values is not an easy job. Livestock forage is not their only crop. They possess, in addition, important watershed, wildlife, recreational, and timber values. To keep pace with rapidly changing conditions western range management already requires, in addition to the contribution of sound practical experience, much detailed knowledge not yet available. Yet, as previously pointed out, interest in basic fact finding has lagged far more on range problems than, for instance, on farming problems. As the men charged with range administration began building up the system of regulated grazing on public range lands, the incentive for digging out new needed facts had to come chiefly from land-managing conservation groups. Consequently, the realization of the need for range research has developed slowly.

APPRAISAL OF RANGE RESEARCH AND EXTENSION ¹⁹

Research on problems concerned with range land use thus far undertaken in the United States may be appraised by discussing briefly duration of the work, character of investigations and agencies engaged, expenditures, number of workers, and application of results in range extension.

DURATION OF WORK

The United States was one of the first countries to undertake research on range-land problems. Investigations by Federal and State agencies began about 1900, and by 1910 eight State agricultural experiment stations had each pioneered one or two projects. In 1907 the Forest Service initiated range investigations in connection with administration of the national forests and in 1910 established the Office of Grazing Studies. Twenty-five years earlier, however, when the great cattle boom of the eighties was at its zenith there was an acute but unrecognized need for research results. Had the facts been known then concerning grazing capacity, seasonal use, and the economic consequences of range abuse, much of the disastrous depletion that began with the boom period and grew with succeeding expansion, might have been avoided. Research started about a quarter of a century too late, and has never been on a scale commensurate with requirements.

¹⁹ In preparing this section, reference was made to publications and unpublished records of the Department of Agriculture, the Forest Service, the Office of Experiment Stations, the Bureau of the Census, the Bureau of Animal Industry, the Bureau of Plant Industry, the Bureau of Agricultural Economics, and the Western States Extension Conferences.

CHARACTER OF INVESTIGATIONS

The Forest Service, charged with departmental responsibility for research on timbered and nontimbered ranges both within and without the national forests, is the only agency that has developed a comprehensive range-wide investigative program. Its work centers on the range resource itself and is only incidentally concerned with the handling of livestock. Emphasis has been on the determination of the principal forage plants, their growth habits and forage value, on range management, including natural revegetation and principles of grazing use, and on the relation of range use to watershed protection. Some progress has also been made on the effects of grazing on forest reproduction, and on plant succession—how vegetation is affected by grazing, drought, and other influences.

Forest Service range research is now confined to a limited number of the important classes of range in five major regions in the West. It is urgently needed, and should be extended to all the principal classes and to the Pacific Northwest.

Eight other Federal agencies, six in the Department of Agriculture, either have cooperated with the Forest Service or have worked independently on the range problems within their jurisdiction. For example, the Bureau of Plant Industry in the early days investigated certain phases of range revegetation, and more recently has devoted increasing attention to pasture problems, development of forage crops, and plant breeding. The Bureau of Animal Industry has studied animal husbandry and poisonous plants; the Bureau of Agricultural Economics, cost of production, ranch organization, and other range-land problems. The Biological Survey has studied wildlife; the Bureau of Entomology and Plant Quarantine, insect problems; and the Bureau of Chemistry and Soils, plant analyses and soil problems relating to range lands. The Bureau of the Census of the Department of Commerce has for many years collected statistical data on livestock, livestock products, pastures, forage crops, and farms and ranches. The Tariff Commission has conducted investigations of manufacturing costs and returns on such range products as wool and beef cattle.

The State agricultural experiment stations in each of the 17 Western States have individually undertaken some work on a variety of problems, centering on range management, animal husbandry, and economics. Limited research is under way at most of the 13 colleges and universities that offer detailed work in grazing. The Carnegie Institution of Washington and the Boyce Thompson Institute for Plant Research have both investigated problems that bear directly or indirectly upon range vegetation.

The research by all agencies for convenience of comparison may be arranged in three groups. The most effort has been expended in group 1, the least in group 3. None, however, has adequately met the needs of the problems.

Group 1	Group 2	Group 3
<ol style="list-style-type: none"> 1. Range management (systems of grazing, livestock distribution, etc.). 2. Range botany. 3. Range animal husbandry (breeding, supplemental feeding, diseases, etc.). 4. Range ecology (changes in range vegetation under various influences and treatments). 	<ol style="list-style-type: none"> 1. Natural revegetation. 2. Effect of grazing on forests. 3. Range economics. 4. Artificial reseeding. 5. Nutritional value of range plants (including chemical analyses). 6. Watershed management. 	<ol style="list-style-type: none"> 1. Grazing capacity. 2. Range wildlife. 3. Degree of utilization. 4. Range soils. 5. Range weather. 6. Range entomology. 7. Range plant breeding.

Both the number of agencies engaged in research on range problems and the number of range-research projects undertaken—90 by the Forest Service and 140 by the State agricultural experiment stations—give a misleading impression of the amount of effective and lasting work performed. Many of the agencies are interested in only one or two local problems; and emphasis in their research, which is often empirical in character, depends to an appreciable extent upon individual initiative rather than upon a planned, coordinated investigative program. Many of the projects, particularly in the early days, were small part-time jobs for one man, requiring less than one man-year of work for completion, as, for example, the chemical analysis of a poisonous range plant. Moreover, a great deal of the first work was as much range extension as research, consisting in a large measure of experimental demonstrations designed to create among range land administrators and stockmen a better understanding of range problems and their important phases. A considerable portion of the early research, although of real value at the time, was empirical and extensive in character, and has been shown in the light of subsequent intensive investigations to have little application to present-day conditions except to solve local problems and to serve as background for future studies. Effective research, that comprehensively attacks region-wide problems and determines urgently needed facts, is largely a development of the last decade.

The Forest Service has effectively organized and coordinated its effort between various problems, lines of work, and range regions. It has recognized the national significance of range research and planned the comprehensive range-investigative program explained in detail later in this report.

EXPENDITURES

It has been estimated that 100 million dollars are spent annually on research in the United States. Nineteen million was spent by the Federal Government alone in 1933; of this, research on range problems in all their aspects, drew not over \$175,000, or less than 1 percent. An additional \$75,000 was invested by State agricultural experiment stations. In 1900, range livestock was valued at approximately 280 million dollars, but only a few hundred dollars of Federal funds were spent in range research proper. By 1930, the range-livestock value had increased to 770 million dollars, and about \$130,000 was expended in Federal range research, or about 0.02 percent. Contrast this with relative expenditures for research in some other agricultural industry such as poultry or dairying. In 1930, the value

of range livestock exceeded the value of poultry raised by 120 million dollars and yet no more Federal money was spent for range research than for poultry research, all of which was essential. From 1900 to 1930 the value of dairy products has consistently been from two to two and one-half times the value of range livestock. But during the same period Federal expenditures in dairy research have exceeded those for range research by 350 to 400 percent. Considering the greatly increased values that have come from these dairy studies, no one would question the desirability of continuing or even expanding them.

Federal expenditures in research on range problems are limited almost exclusively to the Department of Agriculture.

From incomplete estimates, the value of range livestock and corresponding Federal expenditures in range research expressed in dollars and percent of value are as given in table 29.

TABLE 29.—Comparison of livestock values and range research 1915–30

Year	Value of range livestock	Expended for Federal range research		Year	Value of range livestock	Expended for Federal range research	
		Amount	Percent			Amount	Percent
1915-----	\$300, 000, 000	\$50, 000	0. 017	1925-----	\$550, 000, 000	\$100, 000	0. 018
1920-----	810, 000, 000	75, 000	. 009	1930-----	770, 000, 000	130, 000	. 017

NUMBER OF WORKERS

There are probably less than 100 technical workers devoting their full time to research on range problems in the United States today. Because much of the work is not full time and varies greatly from year to year, it is impossible to estimate accurately the total man-years of work done in any calendar year. A generous estimate would be 125 man-years of work annually. The Forest Service performs about 45 of these man-years of work, other bureaus of the Department of Agriculture about 25, the State agricultural experiment stations about 45, and the remaining 10 are scattered among colleges, universities, and other research agencies.

Approximately 50 percent of these workers are engaged in research on conservation and management of the range forage resource, which includes investigations in range and watershed management, range reseeding, range botany, etc., 20 percent are in range-animal husbandry, 15 percent in range economics, largely at the State experiment stations, and the remaining 15 percent are distributed in the fields of range wildlife, range weather, range soils, and range entomology.

RANGE EXTENSION

Range extension is the making available to stockmen and range-land administrators by demonstrations, discussions, addresses, and publications the results of studies and experience. Although research on range land problems has been far from adequate, the results that have been obtained have not been applied on the ground to their fullest possibilities. One main reason has been the lag in

extension work which is the intervening step between research and the practical application of its findings.

In the United States, range extension was to a large degree merged with research until about 1920, and was practically nonexistent as a distinct activity. Since 1923, when a definite range-extension program was first formulated, the extension services of the State agricultural colleges, cooperating with the State agricultural experiment stations and the United States Department of Agriculture, have reported a limited amount of work in each of the 11 Western States, principally in animal husbandry, rodent control, and improved grazing methods. Despite admirable results from the demonstrations and other work already performed, extension specialists attribute the pronounced lag in range extension primarily to (1) high cost of demonstrations, which in order to be effective involve comparatively large areas and herds of sheep or cattle, and (2) inadequate control and administration of the unregulated public domain, resulting in an indifferent attitude of many stockmen toward improved range methods.

EXAMPLES OF NEGLECTED UNSOLVED PROBLEMS OF RANGE RESTORATION AND MANAGEMENT

Studies undertaken to date, as thus outlined, have covered a rather wide scope and have contributed highly useful data; but actually they represent a thoroughgoing attack on only a small fraction of urgent vexing questions that constantly arise to plague the stockmen and land administrator. Facts, clinched by convincing proof, on complex and controversial points are especially inadequate for correction of much range depletion. This serious lack of basic management information applies over a surprisingly large sweep of problems relating to range plants, to animals, and to their environment.

What are some of these challenging management problems of both public and privately owned grazing lands? A few examples will indicate how far research must still go to provide an adequate basis for their solution.

PROBLEMS OF GRAZING CAPACITY

General studies and observations on grazing capacity have for sometime been conducted throughout the West, but intensive studies have been started in only a few places and on a few kinds of range, and chiefly within the last decade—years after their need was painfully apparent. As for other agencies, in the 17 western range States with their multitude of different forage types and varying management needs, only seven State agricultural experiment stations (New Mexico, Arizona, Nebraska, Nevada, North Dakota, California, and Washington) had published by 1920 results of grazing capacity studies. Even in 1930 (15) only two additional stations (Colorado and Texas) were undertaking even limited work in this field (155).

Research on grazing capacity has not yet been conducted on many important western range types.

THE ROLE OF VEGETATION IN WATERSHED PROTECTION

Western grazing lands no longer are valued for their forage crops alone. In fact, on many areas, as will be made clear later in this report, forage values are far outweighed by watershed values which directly or indirectly affect big populations and enormous investments in agricultural and urban facilities and industries. It is imperative, therefore, that management of range lands that are also watershed lands take into account their future productivity not only of forage but also of usable water, the most valuable "crop" in many localities of the West. The objective on such lands is a type of management that so far as possible will harmonize grazing with watershed needs.

Protection of watersheds, one of the primary reasons for the establishment of the national forests, has been given special consideration by the Forest Service for 25 years and more. Noteworthy among the findings of studies and controlled experiments which have been conducted in several localities, is the further evidence, both vegetational and geologic, of the influence of plant cover on surface runoff and abnormal erosion, in relation to grazing. Western ranges and watersheds, however, comprise a complex pattern of soil, topography, vegetation, and climate. Consequently, numerous phases of this big problem, so closely tied in with the welfare of western communities, remain unhandled.

The local and national importance of these problems pertaining to forage-and-forest influences, discussed in detail later in this report, argues for the speedy gathering of a more adequate supply of measured facts.

KEY FORAGE PLANTS

What are the most important range plants in the various grazing types and regions, evaluated as to their growth requirements, forage value, or response to climate? Nelson (93) has shown, in connection with growth requirements and limits of resistance to grazing, that utilization of black grama in excess of 80 to 85 percent of the foliage at the end of the grazing season results in smaller forage crops in succeeding years. But what is safe closeness of use for many other important forage plants and types in other regions? Also, from the dual standpoint of animal nutrition and forage maintenance, what is the proper season of range use, type by type? And again, much observational information has been gathered throughout the West; but detailed data are available for only a few localities and a few sets of conditions.

What is the exact effect of climate on forage plants and on forage yield? A relatively small amount of investigation at the Southwestern, Intermountain, and Northern Rocky Mountain Forest and Range Experiment Stations, the Arizona and New Mexico Agricultural Experiment Stations, and the Carnegie Institution of Washington has yielded detailed data, but on only a mere fraction of the important range plants of the West. The species studied vary greatly in behavior; what about the other equally important plants and their relation to range management? Meager data and general observations of protected plots have further shown the wide fluctuation in forage yield and grazing damage between successive years,

but the combined range damage from drought, overgrazing, and, locally, rodents has not been unscrambled and the causes separately evaluated.

ARTIFICIAL REVEGETATION

What are the possibilities of successfully restoring the grazing and watershed-protective values of depleted ranges by artificial means when nature is too slow? The complete answer to this very practical question is not yet known. The opportunities offered for range revegetation by direct seeding or transplanting of native forage species or exotics have never been adequately explored. Still, the work already done in this field, with a limited number of plant species, indicates considerable promise under favorable conditions and has pointed out the need for more comprehensive testing.

Success has been attained in numerous depleted mountain meadows. Obviously, however, species that are suited to high mountain areas on which precipitation is favorable are not generally adaptable to the more arid foothill and desert ranges at lower elevations. What forage plants can be established successfully on depleted portions of these semiarid grazing lands? What are the limitations in site, in time, and in cost? What possibilities are there for improving species or strains of range plants? What are the practical tests for determining which treatment is most practicable: (1) Artificial revegetation, (2) natural restoration, or (3) a combination of the two? The Bureau of Plant Industry and the Forest Service—the pioneers in this field, along with the several State agencies—have shown that, within limits, artificial revegetation holds much promise. But a maze of unsolved problems lies ahead.

INTERPLAY OF ANIMAL FACTORS IN THEIR EFFECT ON RANGE

Only the merest start has been made on the complex problem of forage provision and management for game animals on livestock ranges. Wildlife management is just beginning to receive widespread attention from the research angle. As yet few studies have yielded a scientific basis for dealing with large numbers of both classes of animals. Meanwhile, local overgrazing of jointly used ranges continues.

Illustrative of the unsolved nature of problems in the wildlife field is the difference of opinion relative to rodents. Any attempt to evaluate rodents in relation to range at once raises the question: Are rodents beneficial or detrimental? Or, more specifically, are rodents, particularly pocket gophers, an essential factor in preserving the proper plant cover on the range, or are they a factor in range depletion including erosion? Obviously, the questions have many angles and various answers, depending on the species of rodent, the kind of range, and other local conditions. Adequate factual information upon which to settle these questions is lacking. Uncertainty and local controversy have, of course, resulted. The greatest immediate need is additional research concerning the life histories of range rodents, the relations between burrowing animals and watershed conservation, and the influences of burrowing animals upon the range vegetation.

NEED FOR SIMPLE, USABLE MEASURES OF RANGE CONDITION

In shifting attention from range animals to the range itself, one encounters a widespread need for simple, usable measuring sticks of range condition. This need is especially surprising in view of the fact that considerable attention has been devoted quite logically to the old but still moot questions: What constitutes proper utilization? Or overgrazing? For certain types and plants, more particularly on the national forests, fairly adequate indicators of range condition are available. In dealing with the less obvious conditions, however, and with unfamiliar vegetation types not yet studied in detail, size-ups of range condition lack uniformity, invite unrecognized damage, and may even become controversial—and they are likely to so continue until more simple, usable measuring sticks, demonstrable on the ground, are available. Their development constitutes a real challenge to research.

MANY OTHER UNSOLVED PROBLEMS

In addition to these examples of unsolved or partially solved problems, a long list of other important ones in such fields as forage values, range-plant moisture and other site requirements, range-plant breeding, range economics, soils, and range entomology are indicative of the scope of the research job ahead. A multitude of facts must be unearthed to answer such questions as: (1) How may western range condition be recognized and evaluated with greater certainty and simplicity? (2) How may range forage be most adequately improved and maintained and range soil safeguarded? And (3) how may the range as a basic resource be handled to make its maximum contribution to social welfare?

THE NET RESULT—A CONCLUDING APPRAISAL

In essence, there are two—and only two—approaches to land-management policies and practices: (1) The slow evolution of rule-of-thumb large-scale trial-and-error experience, and (2) tested facts. The rule-of-thumb approach, by and large throughout the West, has failed thus far to develop management that has stood practical test as witnessed by the practically universal depletion. Research has been, and still is, woefully inadequate in furnishing proven facts to strengthen, where needed, a better factual basis of management. Many needed management facts have accumulated too slowly for maximum effectiveness; and on other problems, no studies have as yet been started. The meager yield of experimental results on obscure or controversial points has never caught up with the increasing need. The resultant lack of dependable information on especially complex problems has thus failed to provide a basis for curbing much continuing depletion, has retarded application of corrective measures on Federal lands, and has delayed extension efforts among private owners.

RESEARCH AND EXTENSION PROGRAM

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WHY RANGE RESEARCH AND EXTENSION?

Every section of this report, in one way or another, reflects the inadequacy of present handling of the range resource and the need for technical information as a basis for range restoration and management. Lack of knowledge, the inevitable result of the lag of research, has been an important factor in the widespread overgrazing, unseasonable use, and other mismanagement now prevailing. Lacking usable ways of measuring range deterioration, it has often not been recognized until production failed in critical periods. Consequently, the 38 percent of the Nation's land area in range fails to yield its maximum wealth and social benefits.

Calf and lamb crops are only one-half or two-thirds as large as they should be; animals develop poorly; and markets, profits, credit, and other financial aspects of the livestock industry are adversely affected. Lands, incapable of supporting families on a satisfactory living standard, remain in private hands, draining the life savings, as well as the hopes and aspirations of their owners.

The present flood menace, impaired stream flow, and serious silting of irrigation and other reservoirs, which directly or indirectly affect most western communities and nearly 20 million acres of irrigated lands, have been allowed to develop. These conditions are chiefly due to deterioration of range cover and the resulting abnormal erosion of range lands as indicated by studies so far made. These studies in turn stress the immediate need for greatly expanded research to determine the necessary understanding of grazing, soil, and other watershed relationships.

The conflicts between grazing and wildlife, the destruction of food and cover, and the silting of streams, have limited hunting, fishing, and other recreational opportunities.

That such conditions need not prevail has been demonstrated by the better resource, social, and economic conditions on national forests and on those private ranges where better management, based on research, has been practiced. Even there, however, the lag of research has been a tremendous handicap to restoration of range, watershed, and other values and in securing the maximum return from sustained production of forage and livestock.

Viewing the range situation in its broader aspects, a program of research and extension sufficiently comprehensive to meet national, regional, and local requirements is justified:

1. To develop management principles and other necessary means to insure restoration, within a reasonable period, of range values on the 675 million acres—93 percent of the range area—which is now depleted.

2. To develop the management principles applicable to the range area and its component parts which will insure sustained forage and

livestock production and maximum returns to livestock producers and the public generally.

3. To develop satisfactory understanding of the interrelationships of the various uses and services of range lands, which include grazing by domestic livestock and game, timber production on forest ranges, watershed protection, and recreation; and to determine adjustments necessary to safeguard values and gain the greatest public benefits.

4. As a basis for developing sound administrative policies for the 353 million acres of range land now publicly owned or controlled.

5. As a basis for determining what areas should remain in private ownership and what should be acquired by public agencies because of submarginality or high public values.

6. As an aid to the private owner of range land and of the livestock grazing on all ranges, in restoring range values, improving management, bettering marketing and credit facilities, equalizing taxation, developing economic units, integrating range land production and use with crop and other related agriculture, and generally increasing the social and economic security of the 4-billion-dollar range livestock industry and dependent communities.

7. As an aid in and basis for national, regional, and local land-use planning and the development of private and public policies, affecting the range area.

MAJOR LINES OF RESEARCH REQUIRED

Research on range lands may be grouped into several broad lines of work including, among others, range management, artificial revegetation, watershed management, range economics, wildlife, animal husbandry, and entomology.

RANGE MANAGEMENT

The purpose of range-management studies is to develop methods of grazing, consistent with the conservation and use of other resources of the land, that will, under the fullest possible use, restore and maintain the forage and produce livestock most effectively. Range management as here used is considered to include such fundamental research as ecology, soil science, and other botanical studies essential to an understanding of the growth requirements and growth habits of range plants, and their response to grazing. It also includes studies necessary in the development of systems of grazing, in determinations of grazing capacity and proper seasonal use, in improving methods of handling livestock on the range, and in developing other features of range use by domestic livestock. These studies center primarily on the range resource and deal with problems of handling livestock on the range primarily from the standpoint of range forage use and more economical handling.

As has been indicated earlier in this report, forage conditions differ widely throughout the range country; this variation has been intensified by various degrees of depletion, both of forage and soil, within each main forage type. Preliminary studies indicate that, if given the chance, the climax species in each type, generally de-

sirable grasses and other plants, will maintain themselves or even improve if not too seriously depleted. In many cases, where the stand of such plants has been greatly thinned, aggressive secondary species have occupied the soil, or the soil fertility has seriously diminished, it will take time and very careful management, adjusted to growth needs of the better plants, to restore a satisfactory cover.

The complex character of the present problem is illustrated by the extreme demand for spring-fall range in the intermountain region. Because of abuse the valuable perennial grasses have been largely replaced by sagebrush and the aggressive annual downy chess, or "cheat grass." Lacking better feed, stockmen graze this vegetation during the few weeks it is green and thus prevent the reestablishment of more valuable perennial grasses, which would ultimately furnish more abundant feed for a longer period. The development of management which will accommodate as much as possible of the grazing demands and yet facilitate restoration of a better cover, requires study of all the involved factors as well as an understanding of the practical needs.

PROGRESS AND NEEDS

Progress may be grouped into three broad phases: (1) The development or improvement of management principles; (2) the determination of some of the more important relationships between livestock grazing and other uses of the range; and (3) the development of some of the fundamental knowledge, basic to the management of the range resource.

Under management principles the outstanding results include: (1) Recognition of the necessity for conservative stocking of ranges on which perennial bunchgrasses are dominant to assure sustained forage and livestock production and to provide a feed reserve for drought contingencies; (2) the development and improvement of several systems of grazing which, with modifications to meet local conditions, have rather wide application, such as the deferred and rotation system which permits full use of the forage but delays grazing until after seed dissemination on a different portion of the range each year; (3) important modifications in seasonal use of mountain ranges to lessen or avoid damage to forage or soil; (4) a fairly good basis for determining the approximate grazing capacity of the mountain range types and some of the more arid types; (5) improved methods for grazing sheep and goats, such as open and quiet herding, and bedding them down in a new place every night, to avoid damaging the range through trampling and localized overgrazing; and (6) obtaining better distribution of cattle on the range through well-placed watering places and better salting methods, thus bringing about more even and more effective use of the available range forage.

The application of these results, particularly on the national forests, has hastened restoration of depleted ranges and facilitated better livestock production and greater stability of that portion of the industry. They illustrate the value and applicability of range research. The success of these results, however, stresses the opportunity for still further improvement through research.

On the Coconino Plateau in the Southwest and various other localities, the main causes of damage to timber reproduction from livestock grazing have been determined, and principles of management are being developed which indicate that most of the damage can be overcome. Much additional research of this kind will be essential as forest practice and range management become more intensive.

A start has also been made in the Southwest and Intermountain Regions in determining the general relation between grazing and watershed protection. Soil is the basic resource. Satisfactory forage and other growth depends upon its maintenance. Water from range watersheds is of vital significance to the West. The prevention of the silting of reservoirs is also outstandingly important. Excessive grazing has so generally impaired watershed values that range-management research must consider watershed needs.

Only a meager beginning has been made in determining the relationship between domestic livestock grazing and wildlife conservation. Most studies have emphasized one phase or the other. The increasing numbers of wildlife, however, greatly intensify the need for a full understanding of these relationships.

The quest for fundamental information, which will undoubtedly furnish the basis for the big advances in potential range management, has but begun. Considerable general information, largely observational, has been collected regarding the forage values of range plants, based upon the extent to which they are eaten by livestock. Similar observations of the habitat relationships of many of these plants have been made. Their classification and description are well advanced. The chemical characteristics and poisonous properties of many of the more important poisonous plants have been determined. On the other hand, the growth characteristics, habits, requirements, physiological processes, including the chemistry of growth, reproduction, food storage, etc., of range plants and their reaction to grazing, have been studied in detail only for a few of the most important plants and in a few localities. This is also true of the competitive relationships, response to climate and soil, and other requirements of the associations of range plants.

In brief, the research performed to date has furnished a fairly satisfactory background for a demonstration of proper grazing in the national forests through determination of a few of the main principles underlying forest-range management. It has made, in a few places, a satisfactory beginning on some of the fundamental problems underlying forage development and use. In several localities research has shown that damage to forest reproduction and watersheds may become very serious; it has indicated, in part at least, the remedial or control measures which are effective.

Future work, requiring most emphasis, includes a more comprehensive and fundamental determination of: (1) The palatability and nutrition value of each of the plants which compose the range forage; (2) the life histories and ecological relationships of all forage plants and associations; and (3) the ecological and physiological reaction of all plants to livestock use. The results of these three groups of investigations will be invaluable guides in applied research and in the application of range management.

The outstanding problems of applied research concern the further perfection of systems of grazing and a more exact determination

of grazing capacity, including the effect of its many influencing factors, and the perfection of livestock management on the range. All research, however, whether fundamental or applied, must constantly consider such primary requisites as preservation of soil and cover conditions so essential not only to the production of maximum forage crops but also for satisfactory maintenance of other land uses and services.

ARTIFICIAL REVEGETATION

The principal objective in artificial revegetation research is to develop low-cost methods and suitable species for seeding or transplanting on 38 million acres of range lands now so badly depleted that reasonably rapid natural revegetation appears improbable. At least one-fourth of this depleted area consists of abandoned fields where cultivation has completely destroyed the native sod. Both forage for livestock and watershed protection values are at stake. If suitable species and low-cost methods can be developed for large areas of semiarid range, the total acreage to which these investigations would apply would be greatly augmented.

PROGRESS AND NEEDS

Various tests of cultivated species, already in use in more humid parts of the United States, have been made on certain western mountain ranges. Kentucky bluegrass and timothy, among others, have proven adapted to favorable sites where soil and moisture conditions are satisfactory. A badly denuded range in the Wasatch Mountains of central Utah, for example, which required about 10 acres to support a sheep for 3 months, was sown to Kentucky bluegrass; at the end of the ninth year 1 acre of this artificially reseeded range would support a sheep for the 3-month season. Crested wheatgrass and smooth brome have proven of value for use under somewhat drier conditions on northern ranges. Most of the seeding tests, however, indicated that the plants tried were unadapted, especially on semiarid areas. It is just as important to ascertain that certain plants are unsuitable as it is to determine which ones can be used, in order to avoid useless expenditures on large-scale attempts at artificial reseeding.

A few of the more important native grasses, such as slender wheatgrass and mountain brome, have proved especially valuable for range reseeding purposes; several other herbaceous plants and some shrubs have demonstrated their worth for reseeding or transplanting for erosion control.

As yet no satisfactory plant material has been found for artificially reseeding semiarid ranges; transplanting under such conditions is costly. Notwithstanding, millions of acres of those lands demand rapid restoration because of large dependent values for watershed protection, livestock, and game. The spring and fall ranges in the foothills are of even more critical importance, as but few species have been found suitable for such conditions.

Studies have been conducted in only a few localities of sufficient intensity to determine why artificial reseeding has succeeded or failed. Such investigations are needed, however, in all parts of the West.

Search for promising forage and erosion-control plants should be made in all foreign countries having growth and climatic conditions comparable to our western range area in order, if possible, to supplement the few adaptable introductions now available and the promising native species. Plant breeding, selection, and hybridization, as applied to range species and conditions, hold untold possibilities. High-yielding and disease-resistant strains of wheat and other grains, as well as fruits, have been developed through research. Comparable experimentation with native and introduced range vegetation should yield similar returns and the long hoped for drought-resistant forage plants now so urgently needed for restoration of range and watershed values.

WATERSHED MANAGEMENT

The main objective of range watershed research is to perfect methods of managing ranges that will afford essential watershed protection, including delivery of the greatest supply of usable water, control of erosion, and regulation of stream flow. The determination of methods for managing impaired watersheds to restore their utility is a distinct phase of the problem.

Research, to date, has disclosed that perennial herbaceous vegetation, especially grasses, is the most effective cover for erosion control on semidesert untimbered ranges of the Southwest and on alpine watersheds in central Utah. Such cover is also very important in the open pine stands of Idaho. Research has also indicated the value of restoring the herbaceous cover on depleted ranges in reducing surface run-off and erosion from summer rains, in increasing absorption of precipitation by the soil, in checking summer flash floods, and in improving the productive capacity of the watersheds. It has also given some indication, in a few localities, of the value of erosion-control dams, water-diversion works, contour terraces, *débris* basins, and other similar engineering works.

These rather localized investigations indicate the great value of such research in correcting a situation which has become critical over most of the West. Similar studies should be undertaken in all other important range types and watershed conditions. Depletion is so general that the extent, nature, and causes of present watershed impairment and usable indicators of early watershed deterioration should be defined so that remedial measures may be promptly applied.

Although restoration to virgin conditions is undoubtedly desirable, it will be, at best, a long and slow process in many areas. Accordingly, definite data are needed concerning the most practical cover which can be obtained rather promptly for reasonably satisfactory watershed protection. Determination of the optimum watershed cover for each important condition, however, is also essential. The range cover on watersheds is so closely interrelated to the range livestock industry and the social and economic welfare of the West that additional research is required to determine how much the cover may be modified or utilized without sacrificing its ability to retard run-off, build and bind the soil, aid water percolation, and otherwise control erosion and stream flow.

RANGE ECONOMICS

The major work to date has featured studies of wool production, livestock-production costs in several States, surveys, and a few intensive investigations of ranch organization and management, determination of the basis for grazing fees on the national forests, local land-use studies, and preliminary phases of other economic aspects.

One important phase which justifies early initiation is a comprehensive range-resource and economic survey involving such features as the area, location, and ownership of range land, its actual and potential grazing capacity, and the most effective coordination of the use of range land with other agricultural land. The results in this report have provided a conception of the national and regional extent of the resource, of some of the vital economic problems in range use, and of broad social and economic changes which must be made. It is clearly evident that a more intensive survey providing for an inventory of the range resources and more exact information concerning changes needed is essential to furnish the basis for further national, regional, and local land use and agricultural planning and adjustment. Many of the surveys already completed for development of management plans or recommended in other parts of this report will aid materially in the assembling of necessary information.

Additional studies of production costs and ranch organization are needed to disclose the most economic size of enterprise, the proper balance between range and crops, and how ranch organization may be revised to produce livestock, livestock products, and feeds more economically. Closely related to these are the needs for studies of range-land use, especially the determination of lands submarginal for private ownership. The range-livestock industry will further benefit from more detailed investigations of credits, marketing, taxation, and other financial entanglements which encumber the business.

WILDLIFE

Most research on wildlife has concerned taxonomic relationships, the food habits of a few major species, and the control of injurious rodents and predators. The outstanding problem is to provide a technical background for the restoration and maintenance of desirable wildlife. This should be supplemented by closely related research on life habits and the specific place of each species in its environment. Such basic knowledge will be of great significance in the development of a really effective technology of conservation and control.

If wildlife for food, fur, or recreation is to be produced on the range, where it rightfully belongs—in fact as the maintenance of the desired biological balance in certain cases obligates—particular advantage will result from sustained output. What numbers can be maintained and what may be removed annually without reducing breeding stocks below the safety point must be determined. When these things are known, limitations may be placed on season, age, sex, and numbers that can be removed, based on an understanding

of the life histories and ecological relationships of the animal concerned. That method would be far more permanent and secure than the unsatisfactory empirical foundation upon which existing game laws in the United States are based.

Research should also determine existent values and necessary adjustments in other wildlife. Birds, for example, may spread plant diseases and consume seeds; on the other hand, they also plant seeds and prevent or shorten insect epidemics by preying upon injurious insects. Burrowing rodents improve the tilth of soils. Rodents, however, consume enormous quantities of forage. Predatory animals, such as coyotes, wolves, and mountain lions, although beneficial in their consumption of rodents, often destroy so much livestock that they seriously affect business profits. Control of wildlife detrimental to range and livestock must depend upon the ecological relationships of each animal and its life habits, such as preferences for food.

All problems involving ecological relationships, life histories, protection, and wildlife management, must be attacked not as distinct studies which in themselves are final objectives, but rather as parts of a much broader system of range-land management, which includes forage for livestock as well as wildlife, watershed protection, timber production, recreation, and possibly other uses and services of the land.

ANIMAL HUSBANDRY

The improvement of breeding herds and flocks on the range and the control of diseases constitute the outstanding achievements in range animal husbandry. Much still remains to be accomplished, however, in improving livestock types for range use through selection and breeding, in controlling diseases and parasites which affect range animals, and in studying the economic wintering of range livestock. Improved nutrition for range animals offers tremendous research possibilities, especially since forage depletion necessitates the grazing of many secondary or even low-value species and involves the feeding of essential minerals and other supplements.

ENTOMOLOGY

Range entomology and other special phases of zoological research may be justified where high economic values are at stake. Cases in point include the beet leafhopper and locust infestations in many parts of the West, where the pests breed chiefly on overgrazed range lands and often migrate to nearby irrigated areas, thus causing great damage both to the range forage and cultivated crops.

COORDINATED RESEARCH

The preceding program of research on range lands has emphasized individual lines of investigation with only minor reference to the relationship of one to another, but the inter-relationship of problems and work is obvious. Sound principles of management can be devised only by coordinated study that weighs all values and utilizes the fundamental sciences which bear upon the problem.

Since the range problem is agricultural, its research must logically be coordinated closely with allied research of the Department of Agriculture and the State agricultural experiment stations.

EXTENSION

Range extension consists primarily of educational and demonstrational work designed to disseminate practical information concerning range management. It seeks also to spread applicable knowledge of range management among the owners, users, and managers of range lands and to demonstrate and interpret desirable range-use practices adapted to local conditions in order that range lands may perform their fullest potential services, both economic and social.

A limited amount of such work has been handled by extension livestock specialists and some county agents with desirable results in most of the Western States. Considering the widespread depletion on privately owned ranges, direct assistance to individual range-livestock owners, in formulating management plans and applying improved range practices should be at the fore of any such program. A sound management plan is just as essential for proper handling of the range as is a blue print in building construction. Extension workers should provide stockmen with the latest research results on revegetating the range, on stocking to safeguard against drought losses—in fact, on all the results of the previously outlined studies. Extension also might well popularize cost-keeping systems. The net result of this extension work would be a much-needed coordination of individual welfare and production with regional and national requirements.

RESPONSIBILITY FOR AND COST OF RESEARCH AND EXTENSION REQUIRED

The Federal Government has direct responsibility in range research on Federal lands, on national problems, and on regional problems. The 287 million acres of federally owned or controlled range lands require research as the basis for sound management. The 67-percent depletion on unreserved public domain and grazing districts occurred under Federal jurisdiction, and implies Federal responsibility for restoration. Many of the range problems have national and regional significance. The use of range lands as a part of the integrated agriculture of the West has never been fully appreciated, but its importance is outstanding, not only to the West but to the Nation. Thus, from all aspects, the Federal Government has a responsibility to carry the major burden of research and at least half the burden of extension on western range lands.

Federal research on range problems is conducted primarily by the Department of Agriculture; the Bureau of the Census has compiled valuable statistical data, and the Tariff Commission has made certain studies of wool and livestock production. The McSweeney-McNary Forest Research Act of 1928 authorized range investigations, and under its provisions and the general authorizations of the agricultural appropriation acts the Forest Service has conducted a coordinated attack on range management, artificial revegetation, watershed management, and certain phases of range economics. Such research is now in progress at five of the six regional forest and range experi-

ment stations in the West. Other research has been handled independently or in cooperation with the Forest Service by the Bureaus of Plant Industry, Animal Industry, Agricultural Economics, Biological Survey, Chemistry and Soils, Soil Conservation Service, Entomology and Plant Quarantine, and the Weather Bureau.

The States have a responsibility for range research on State-owned range lands and on local problems. States are also coming to recognize their responsibilities for cooperation with the Federal Government in handling the regional and national problems. All of the State agricultural experiment stations of the 17 western range States have done some work on range problems. Although some of this research has been conducted independently, much has been carried on in cooperation with one or more bureaus of the United States Department of Agriculture.

A broad field of fundamental scientific investigation is open to quasi-public and private research institutions. Many botanists, zoologists, and other scientific workers in colleges and universities have given incidental attention to problems which directly or indirectly affect range vegetation and animal life. Much of the early taxonomic research on range plants was performed in this way, and considerable similar work still continues. Many important discoveries in plant physiology, ecology, and biology have been made by university experimenters. Research opportunities along these lines are practically unlimited, and when combined with graduate work of men in training for range-research positions, may further the entire program. Such agencies as the Carnegie Institution of Washington, the Boyce Thompson Institute for Plant Research, the Southwestern Arboretum, and similar though less prominent agencies may all contribute advantageously to the range-research program.

In developing such a comprehensive program of research a highly trained personnel will be essential. Much of the research up to the present has been preliminary and empirical. That of the future should be more concerned with fundamentals. The demand for well-trained college graduates in range-management work has always been good. For research positions, men with advanced training and of exceptional ability will be needed. To facilitate the development of such men, additional fellowships should be established. They should be available only to the more able men and centered in the stronger institutions.

PRESENT EXPENDITURES

Present expenditures by all agencies for research on range-land problems total approximately \$750,000. Expenditures of the Department of Agriculture cover most of this, primarily centered in the Forest Service.

It is estimated that present expenditures for range extension aggregate approximately \$50,000 annually, wholly insufficient when distributed, although not equally, among 17 States. It is practically impossible to estimate the actual cost because so much of the work has been handled more or less incidentally to other extension activities.

PROPOSED EXPENDITURES

In view of the lag in range research, the present depleted condition of the resource, natural factors retarding range restoration, and the multiplicity of range problems now requiring study, an annual expenditure about four times the present as a 10-year program appears necessary. Of the total annual expenditures of \$2,750,000 required for all research on range lands, which should be reached by 1947, the program of the Department of Agriculture would account for about \$2,000,000 annually. States should assume responsibility for approximately \$550,000 and other agencies about \$200,000. Ten years is a reasonable period in which to expand the research of the agencies involved to the full extent of this contemplated program.

Authorizations for such a research program in the United States Department of Agriculture are already provided in the Agricultural Appropriation Acts and in the McSweeney-McNary Forest Research Act. The latter act authorizes annual appropriations of \$275,000 for "range investigations" (primarily management and artificial revegetation) up to the fiscal year 1938, and after that year for "such annual appropriations as may thereafter be necessary." Specific legislative authorization of at least \$400,000 for the range watershed management investigations is desirable, either independently or as a component part of the proposed national program for watershed research on forest and range lands.

In addition to the above amounts needed for the western United States, funds are required for range research in the South and in Alaska. Probably, \$200,000 annually would meet the needs during the next 10 years for investigations dealing with range use of southern forest lands, with the full amount to be reached in the tenth year. In Alaska, approximately \$100,000 annually will be needed.

The promotion of satisfactory management on the 376 million acres of ranges now in private ownership and of privately owned livestock grazing on publicly owned ranges requires the development of an extension organization during the next 10 years costing approximately \$1,000,000 annually. This involves a joint participation by both the Federal and State Governments, supplementing the existing Extension Service activities. Since county agents and extension specialists are heavily burdened with other duties, the extension program on range-land problems should be carried out by either assistant county agents trained in range management or range specialists each serving several counties as a unit. Supervision should be furnished by the addition of range specialists to both State and Federal Extension forces.



